High Resolution Mesoscale Atmospheric Model Prediction and Validation

Sue Chen
Naval Research Laboratory
Monterey, California 93943
phone: (831) 656-4737 fax: (831) 656-4769 e-mail: chen@nrlmry.navy.mil

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LONG-TERM GOAL

The long-term goal of this project is to improve the high-resolution model forecasts by developing a real-time globally re-locatable capability to initialize/assimilate the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS™)[1] land-surface model soil parameters. The partition of the model surface sensible and latent heat fluxes in the land-surface parameterization is sensitive to the initial soil temperature and moisture content. A proper estimation of the soil conditions thus has many important implications ranging from its impact on boundary layer thermodynamic structure to improvements in modeling the hydrological cycle.

OBJECTIVES

Past studies conducted primarily over Europe and CONUS, have shown that improvements in the soil moisture content led to a positive impact on the prediction of mesoscale weather such as cumulus convection and rainfall. One of the primary challenges here is extending such results for use in the COAMPS land surface model for 1-5 day forecast applications. Thus the objectives of this project are to: (i) develop code infrastructure to examine various soil initialization/assimilation techniques that may be suitable for the real-time COAMPS applications; (ii) investigate the various initialization/assimilation impacts on the precipitation and cloud prediction; and (iii) investigate methods and types of observations that can be used for validating COAMPS cloud predictions.

APPROACH

Our approach is to test the soil initialization techniques currently used by the operational NWP global prediction systems and a recent statistical-based technique developed by the North Carolina State

University for applications in limited area models. The work to examine the feasibility of using an off-line global land-surface model driven by the observed precipitation, radiation, and meteorological soil analysis to initialize COAMPS soil parameters was conducted only in FY03. The remainder of the soil initialization work, including investigating the assimilation strategy for the soil parameters, will be combined with the land-surface modeling effort in a NRL 6.2 base program Improved COAMPS Land Boundary.

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14. ABSTRACT
The long-term goal of this project is to improve the high-resolution model forecasts by developing a real-time globally re-locatable capability to initialize/assimilate the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPSTM)1 land-surface model soil parameters. The partition of the model surface sensible and latent heat fluxes in the land-surface parameterization is sensitive to the initial soil temperature and moisture content. A proper estimation of the soil conditions thus has many important implications ranging from its impact on boundary layer thermodynamic structure to improvements in modeling the hydrological cycle

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For the cloud validation work, our approach is to modify the COAMPS-OS ADAS cloud diagnostic system to allow for verification of cloud layers based on satellite-based cloud top and surface-based cloud base observations.

WORK COMPLETED

Developed software to initialize COAMPS coupled with the National Centers for Environmental Prediction, Oregon State University, Air Force, and Hydrolic Research Lab (NOAH) land-surface model (LSM) soil parameters using the Air Force Weather Agency (AFWA)'s Agriculture Meteorology (AGRMET) Modeling System global soil analysis (approximately 47 km horizontal resolution).

Performed four sets of two-week model simulations in June 2002 and January 2003 over Europe and the Continental United States (CONUS) to examine the impact of different soil parameterization and initializations, e.g. a slab model versus a multi-layer LSM and climatology versus AGRMET soil initializations, to the COAMPS predicted boundary layer structure, cloud coverage, and quantitative precipitation.

Compared the case study results with available observations.

Developed an algorithm to bin cloud tops into layers based on the cloud black body temperatures. Performed one-month of COAMPS simulation using the current slab model in June 2003 over eastern CONUS. Computed cloud top statistics with available satellite and surface observations.

RESULTS

Soil temperature and moisture initialization:
Four sets of soil initialization experiments have been conducted for the two-week periods over the CONUS (81x27 km grid resolution) and the Europe (81 km grid resolution) areas. These include: (a) a slab model initialized with Navy Operational Global Atmospheric Prediction Systems (NOGAPS) ground wetness and deep soil temperature from climatology for the cold starts and with previous COAMPS forecasts for warm starts, (b) a slab model initialized with the AGRMET soil analysis for warm and cold starts, (c) the LSM initialized with climatology for cold starts and with previous COAMPS forecasts for warm starts, and (d) the LSM initialized with the AGRMET soil analysis for cold and warm starts. The simulations are 36- hour forecasts with a 12-hour data assimilation cycle. There is no data assimilation for the soil parameters. These parameters are either re-initialized at the data assimilation time with the AGRMET analysis interpolated to the COAMPS grid using the nearest neighbor method or from the previous COAMPS 12 hour forecast.
COAMPS is known to have a consistent cold/wet surface and lower troposphere temperature/moisture bias. The magnitude of the temperature bias has seasonal/regional variations around -1 to -3 degree C. The Europe results show that the surface temperature and moisture errors are very sensitive to initial soil condition. When comparing the coupled LSM runs initialized with climatology (LSM) and the AGRMET analysis (AGR), in the summer and winter periods, the LSM soil moisture was consistently too dry. The LSM also had a much larger diurnal oscillation. The drier soil allows faster surface heating (cooling) during the day (night), Therefore when averaging the day and night scores, the LSM had a warmer/colder surface bias in summer/winter. Because the LSM surface heats up more during the summer daytime, it was able to correct the cold PBL biases more in summer. While in winter, the

LSM was too cold and dry at the surface. Therefore, the AGR had smaller PBL biases in winter (Fig.1). In general, over the Europe area, the AGR initialization had much better results than using the climatology for both the SLAB model and the coupled NOAH LSM model.

The results from the CONUS experiments are similar. At the surface, the experiments coupled with the LSM had smaller root-mean-errors and biases than the slab runs in summer and winter. Among the experiments that used the coupled LSM model, in June 2002, the experiments using AGR had much better surface temperature and moisture biases than climatology. However, in January 2003, AGR was too dry at the surface. The comparisons of the in-situ 10 cm soil measurements from the Soil Climatology Agriculture Network (SCAN) and the AGR soil analysis showed AGR was slightly moist but too cold during this period. Because of the colder and wetter soil conditions, less sensible and latent heat fluxes were transferred to the surface, resulting in colder and drier surface biases for the AGR runs. The averaged cloud fraction (as seen by the COAMPS radiation scheme) difference between AGR and climatology initialization during these two weeks also showed the AGR had less low- level cloud over most of the CONUS region (Fig. 2). In addition to the surface and PBL statistics, the quantitative precipitation forecast (QPF) was also examined. Although the precipitation patterns were similar for individual days for all experiments at the 27 km grid resolution, the experiments coupled with the LSM had better QPF biases in the medium (10 and 15 mm/day) rain thresholds (Fig.3).

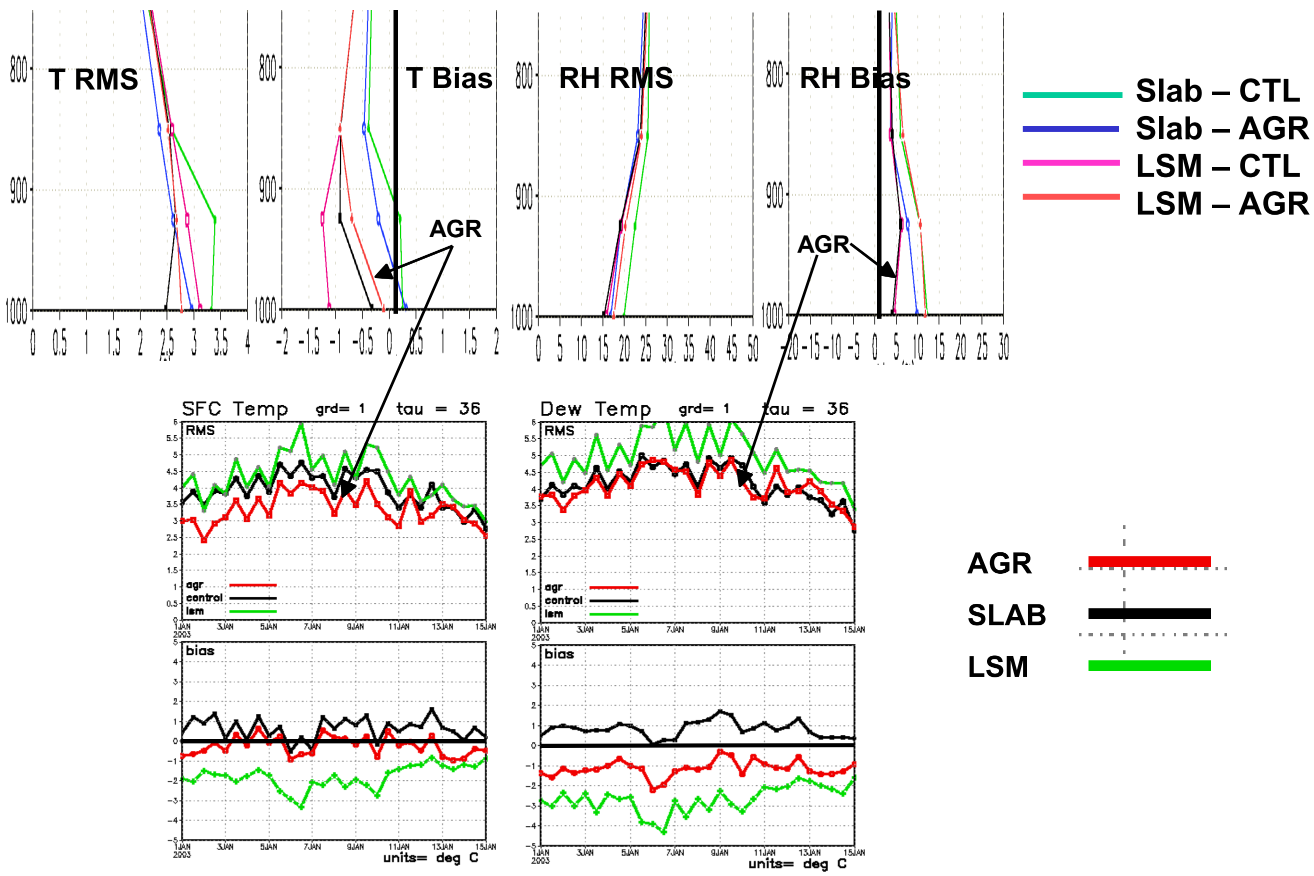


Figure 1. COAMPS lower atmosphere temperature and moisture root-mean-square and bias errors (top four panels). The surface temperature and dew point depression statistics for January 2003 over Europe area are shown in the bottom two panels.

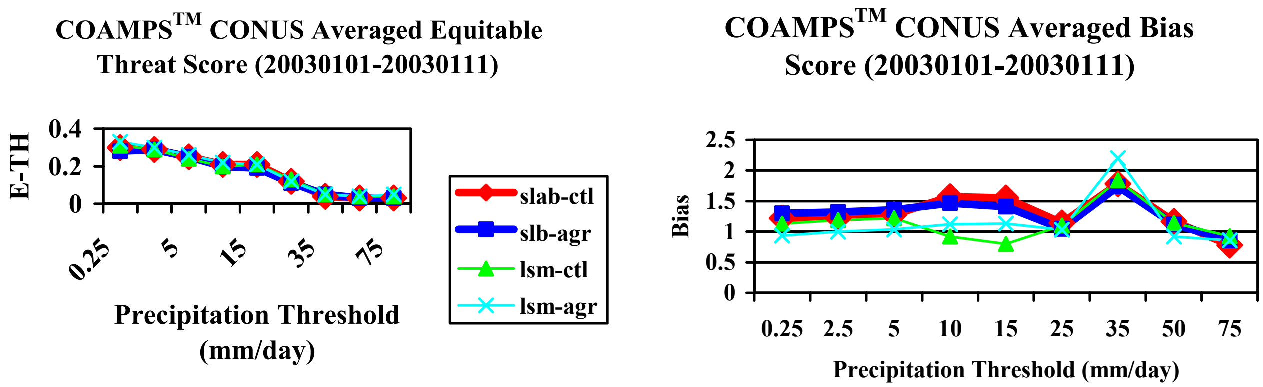


Figure 2. Averaged COAMPS 24-hour accumulated pecipitation equitable threat and bias scores during January 2003.

Cloud tops validation:
Cloud tops were binned into layers based on the cloud black body temperatures. All cloud tops above 400 mb were considered upper tropospheric, all cloud tops between 700 and 400 mb were mid-tropospheric, and clouds between 850 and 700 mb were lower tropospheric. Pressure-level temperatures were derived from the COAMPS forecasts valid at each observation time. No diagnostics were performed below 850 mb due to difficulties in discerning cloud tops from cold surface temperatures. New satellite-based products may alleviate this problem over the water in the near future. Lower tropospheric cloud base statistics were binned based on the height of the lowest cloud base in both the model and the observations. The layer thresholds considered are 100 m, 300 m, 1000 m, and 2000 m. Cloud top statistics derived from the 24-hour 27 km horizontal resolution COAMPS forecasts over the eastern US during 2-22 June 2003 indicate that model cloud tops tend to be shifted upwards in comparison to the GOES 12 satellite observations. The model cloud tops tend to be higher and more broadly distributed than the observations. The results from binning the cloud tops into layers indicate, in the column-total sense, almost all (93%) of the points with observed clouds are also cloudy in the model. However, only 73% of the cloudy points in the model are also cloudy in the observations. This result corresponds to a 27% positive bias in total forecast cloud cover (Fig. 4).

Model predicted upper tropospheric cloud top coverage was up to 8 times greater than that of the observations, while corresponding middle tropospheric cloud top predictions were 4 times less than that of the observations. Visual comparisons of the individual forecasts revealed that the areal cloud coverage was actually quite similar except for the shift in height. Satellite cloud observations retained considerable structure in the upper tropospheric temperature distribution, especially in areas of thin cirrus (Fig.4). However, the model cloud top temperatures were far more uniform over the cloud extent. Much of this was due to the very coarse upper tropospheric grid spacing of about 1 km. Even small amounts of cloud ice or cloud water in these layers greatly increased the cloud deck radiative opacity. This represents a significant caveat for the use of black body temperatures for cloud top diagnostics and verification.

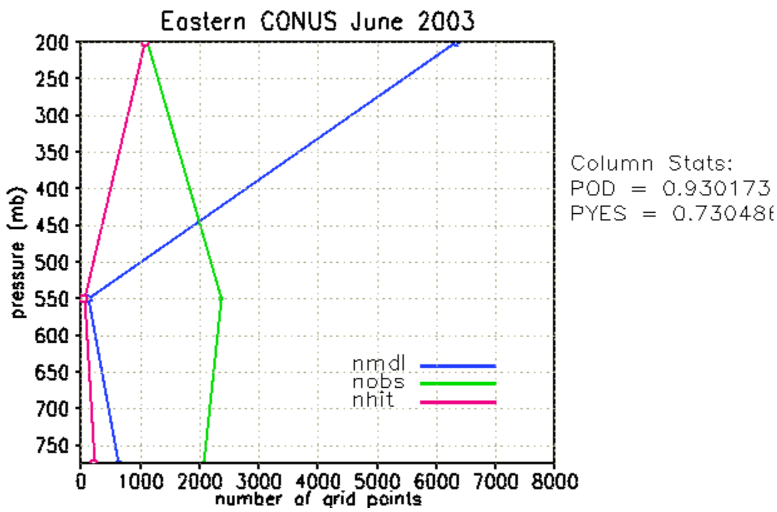
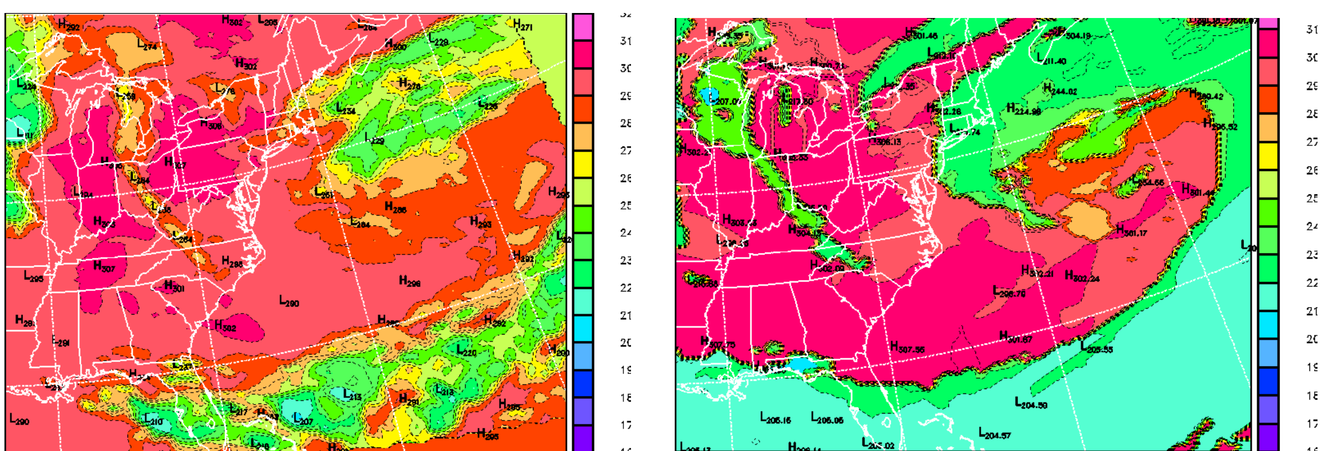


Figure 3. The profiles represent the averaged number of observed cloud top points (nobs), model cloud top points (nmdl) and cloud top hits (nhit). The graph shows that the model cloud tips tend to be higher and more broadly distributed than the observations.



(a) (b)

Figure 4. The cloud top temperature from (a) COAMPS 6-hour forecast and (b) GOES12 satellite obervations valid at 1200 UTC 22 June 2003. The model cloud tops are more extensive and very uniform while the observed tops have far more structure.

IMPACT/APPLICATIONS

The condition of the initial soil state and subsequent soil assimilation are important to the model boundary layer structure and hydrology cycle. This project has demonstrated that using COAMPS coupled with a more sophisticated multi-layered land-surface model, combined with a better soil initialization, can improve the COAMPS lower atmosphere cold and wet biases.

RELATED PROJECTS

Related 6.2 projects within PE 0602435N are *BE-35-2-18*, for the Improved COAMPS Land Boundary Layers, *BE-35-2-44*, for the Advanced Moist Physics Modeling, and *BE-35-2-32* for the Data

Assimilation for Doppler Radar/Shipboard Systems, which has developed the ADAS analysis for COAMPS-OS. Related 6.4 projects within PE 0603207N are, for the Tropical Cyclone Intensity and Structure Via Multi-Sensor Combinations, and for the Small-Scale Atmospheric Models project.

SUMMARY

The soil initialization sensitivity tests have shown that encouraging results can be obtained when using a better soil initialization from the global AGRMET soil analysis.
Future work will focus on developing the capability of a soil data assimilation using the variational method from the NRL Atmospheric Variational Data Assimilation System (NAVDAS)

The cloud-top statistics showed COAMPS has positive cloud coverage bias in the upper troposphere and negative bias in the middle troposphere. However, cloud top processes are not fully resolved in the model due to low upper tropospheric model resolution. Future verification experiments are planned with increased upper tropospheric grid resolution to diagnose the extent of any true over-prediction at that level.

PUBLICATIONS

Chen, S., T. R. Holt, and J. E. Nachamkin, 2003: Sensitivity of the Soil Moisture Initialization to the Prediction of Cloud and Precipitation in the Coupled Ocean/Atmosphere Prediction System (COAMPS^{TM}). 2003 Battlespace Atmospheric and Cloud Impacts on Military Operations (BACIMO), Monterey, CA.

Nachamkin, J.E., 2003: Mesoscale verification using meteorological composites. Submitted to Monthly Weather Review.

Nachamkin, J.E., J.M. Schmidt, C.S. Liou, S. Chen, 2003: Evaluation of improvements of the moist processes in the coupled ocean atmosphere modeling system (COAMPS). Preprints 10th Conference on Mesoscale Processes. Amer. Meteor. Soc., Portland, OR.